Psyche Early Project Verification & Validation Planning and Development

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and the Psyche Team

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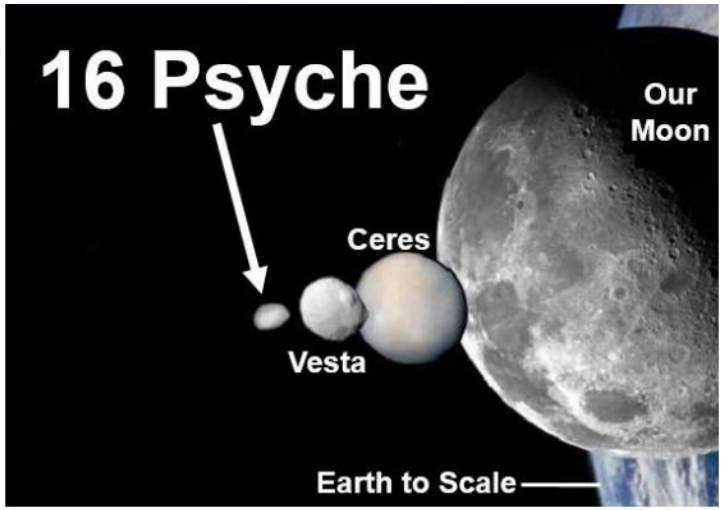
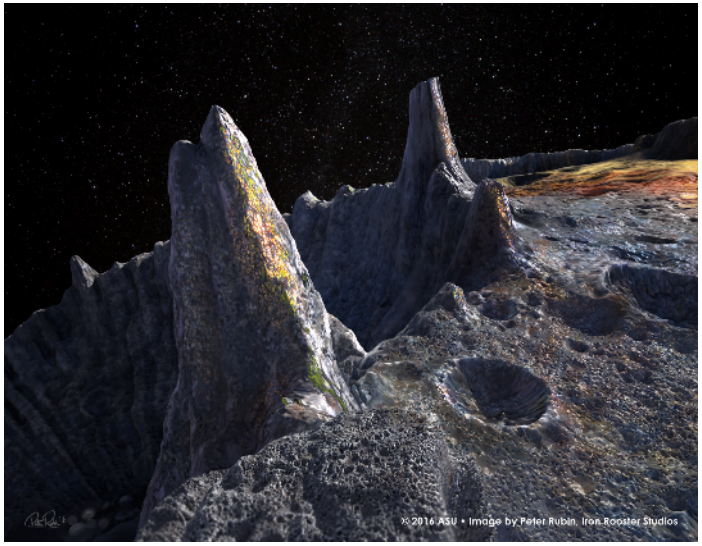
California Institute of Technology

What is (16) Psyche?





- Discovered in 1852 (Naples)
- 10th largest asteroid (largest M-type)
- a = 2.92 AU, e = 0.140, i = 3.09 deg
  - Relatively easy access with solar electric propulsion (SEP)
- Rotation period: 4.196 hours

- High radar albedo
- High density
- High thermal inertia (120 tiu)
- Spectra: 10% silicate, 90% metal

- Strong testable hypothesis
  - *"Is (16) Psyche the exposed core of larger differentiated body?"*
  - *"Was (16) Psyche created by a slow accretion of metal-rich material?"*

Whatever hypothesis is determined, results would be scientifically significant

Psyche High Level Mission Overview

Science Goals

- *Look back in time.* Understand a previously unexplored component of the early building blocks of planets: *iron cores.*
- *Look inside the terrestrial planets,* including Earth, by directly examining the interior of a differentiated body, which otherwise could not be seen.
- *Explore a new type of world.* For the first time, examine a world made not of rock or ice, but of iron.

Mission Description

- Target: (16) Psyche
- Spacecraft Partner: **JPL** flight system w/**SSL** SEP chassis
- Launch Date: August 2022
- Arrival Date: January 2026
- Science Phase duration: 21 months

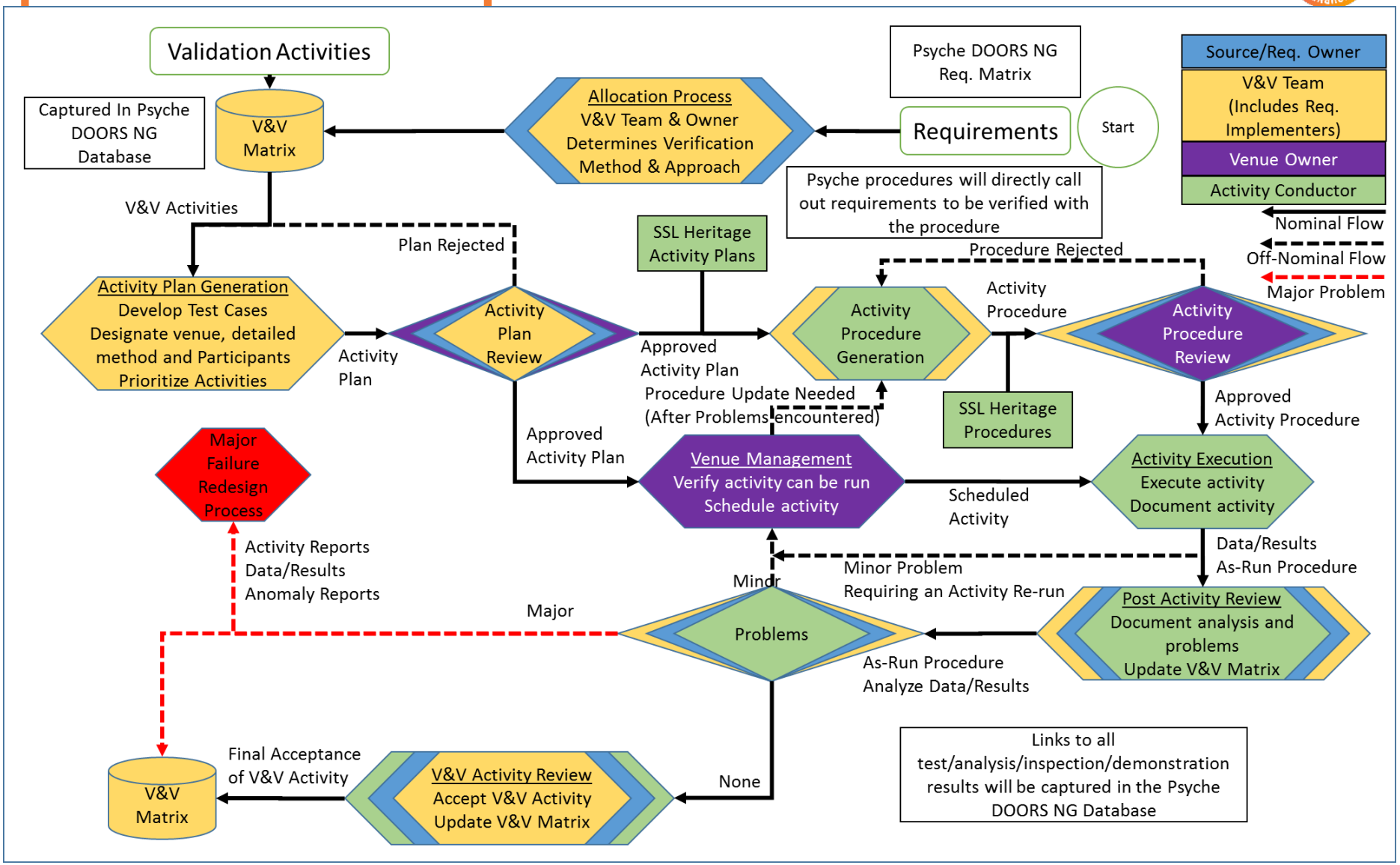
Science Payload

- Magnetometer: MIT/UCLA (MMS/Insight)
- Multispectral imager x 2: ASU/MSSS (MSL heritage)
- Gamma Ray/Neutron Spectrometers: APL (MESSENGER heritage)
- Gravity Science: X-band telecom, no dedicated hardware

Technology Demonstration Payload

- Deep Space Optical Communications (JPL)

Allowed us time to Integrate the JPL V&V process with our partners



Early V&V allowed us to take a hard look at the testbeds that we would need

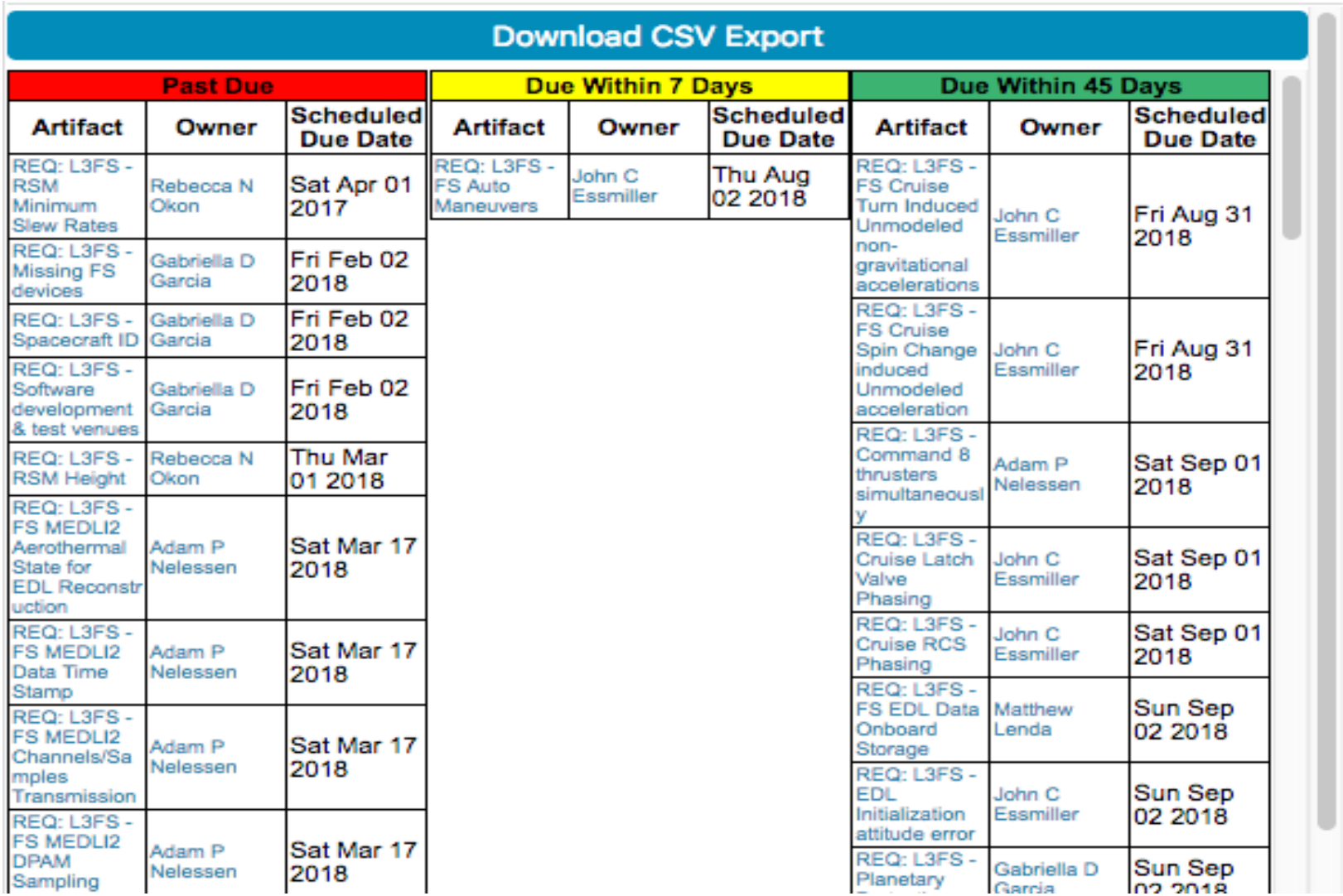
Venue Name	Venue Description
WSTS	• Runs FSW with simulators of hardware • Uses GDS • Used as a dry-run venue prior to higher fidelity tests • Can be (and should be) heavily scripted
FSWTB#1 &2	• Single-string testbed with EM PCE Used for FSW development, Early EM instrument and PDA interface checkout • Used for AVS L4 and FSW L5 V&V testing as each FSW build comes available Includes SSL SEP Chassis hardware simulation • Includes instrument simulations, GN&C simulations, telecom hardware simulations
FSTB	• High-fidelity dual-string testbed • (EM PCE will travel from FSWTBs to FSTB for dual string configuration) • Used for AVS L4 V&V testing • Used for System L3 V&V testing (MSTs, ORTs) and ATLO dry-runs, post-launch anomaly resolution • Used for SSL risk reduction testing during summer 2020 • Includes Dual-string EM PCE, PT PDA • Includes EM SSL SEP Chassis hardware Includes all EM instruments • Includes GN&C simulations, telecom hardware simulations

Test Venue Certification

- All testbeds need to be certified/validated against the flight system
- A fidelity assessment will be conducted for the capabilities needed to buy off System Integration & Test requirements
  - Psyche will compare the flight hardware to:
    - DITL test
    - Functional tests
    - Early testbed interface visits
    - MSTs
- Any deviations will be documented and presented to stakeholders for assessment
  - If necessary, augmentations and improvements will be made to the testbed environments to make the testbed mimic the flight article
  - A Testbed Certification Document will document results of fidelity assessment

- WSTS will only be certified for a subset of functions that satisfy “Intended Use” cases such as: Dry run of test procedures, FP, supplemental V&V venue.

Gave us time to develop new req. tacking tools



Download CSV Export

Past Due

Artifact	Owner	Scheduled Due Date
REQ: L3FS - RSM Minimum Slew Rates	Rebecca N Okon	Sat Apr 01 2017
REQ: L3FS - Missing FS devices	Gabriella D Garcia	Fri Feb 02 2018
REQ: L3FS - Spacecraft ID	Gabriella D Garcia	Fri Feb 02 2018
REQ: L3FS - Software development & test venues	Gabriella D Garcia	Fri Feb 02 2018
REQ: L3FS - RSM Height	Rebecca N Okon	Thu Mar 01 2018
REQ: L3FS - FS MEDLI2 Aerothermal State for EDL Reconstruction	Adam P Nelessen	Sat Mar 17 2018
REQ: L3FS - FS MEDLI2 Data Time Stamp	Adam P Nelessen	Sat Mar 17 2018
REQ: L3FS - FS MEDLI2 Channels/Samples Transmission	Adam P Nelessen	Sat Mar 17 2018
REQ: L3FS - FS MEDLI2 DPAM Sampling	Adam P Nelessen	Sat Mar 17 2018

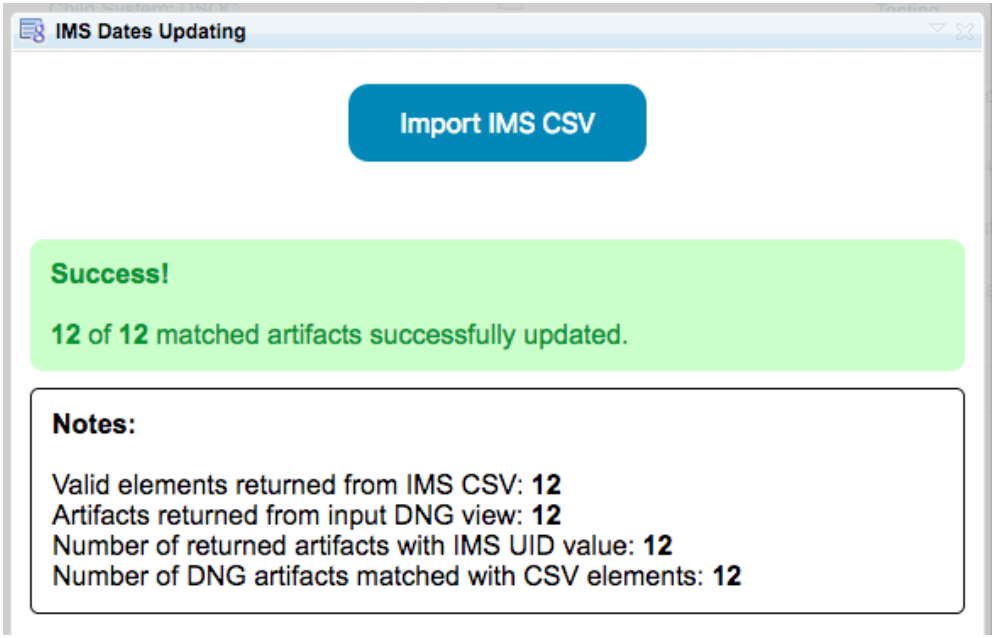
Due Within 7 Days

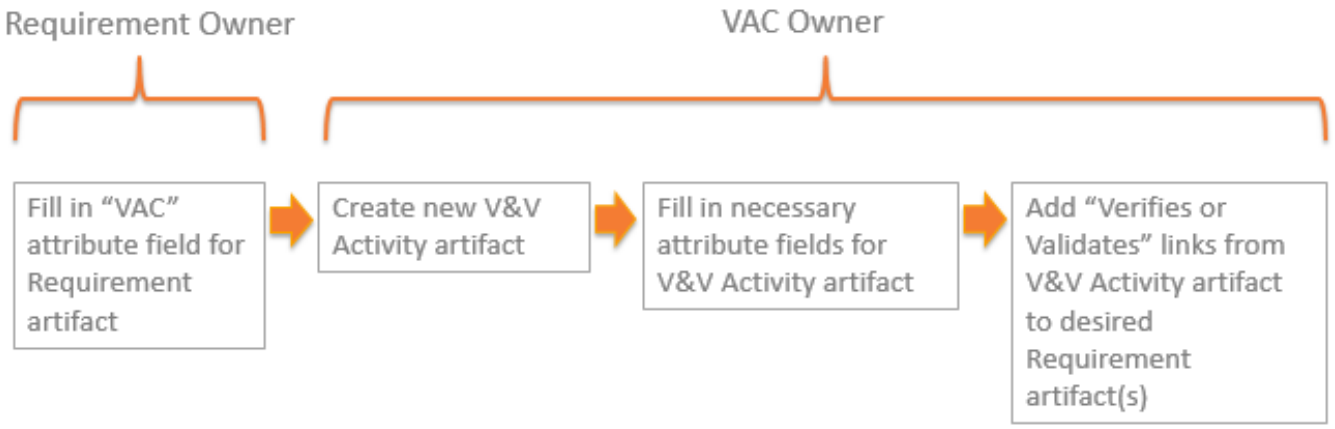
Artifact	Owner	Scheduled Due Date
REQ: L3FS - FS Auto Maneuvers	John C Essmiller	Thu Aug 02 2018

Due Within 45 Days

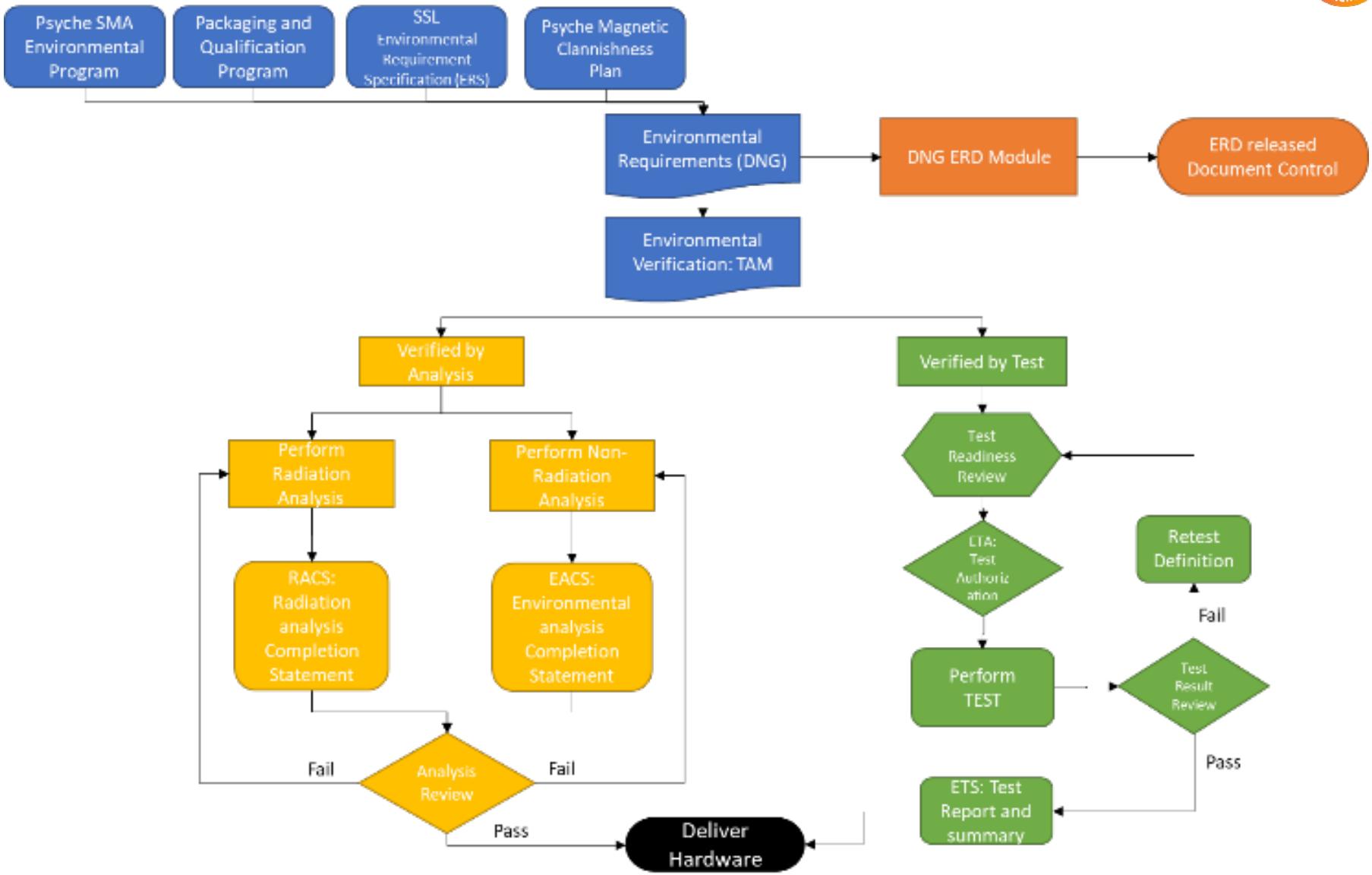
Artifact	Owner	Scheduled Due Date
REQ: L3FS - FS Cruise Turn Induced Unmodeled non-gravitational accelerations	John C Essmiller	Fri Aug 31 2018
REQ: L3FS - FS Cruise Spin Change induced Unmodeled acceleration	John C Essmiller	Fri Aug 31 2018
REQ: L3FS - Command 8 thrusters simultaneously	Adam P Nelessen	Sat Sep 01 2018
REQ: L3FS - Cruise Latch Valve Phasing	John C Essmiller	Sat Sep 01 2018
REQ: L3FS - Cruise RCS Phasing	John C Essmiller	Sat Sep 01 2018
REQ: L3FS - FS EDL Data Onboard Storage	Matthew Lenda	Sun Sep 02 2018
REQ: L3FS - EDL Initialization attitude error	John C Essmiller	Sun Sep 02 2018
REQ: L3FS - Planetary	Gabriella D Garcia	Sun Sep 02 2018

Developed a Method for Linking Verification Activities to the Project Schedule





Working on integrating our Environmental requirements process with the rest of the req.



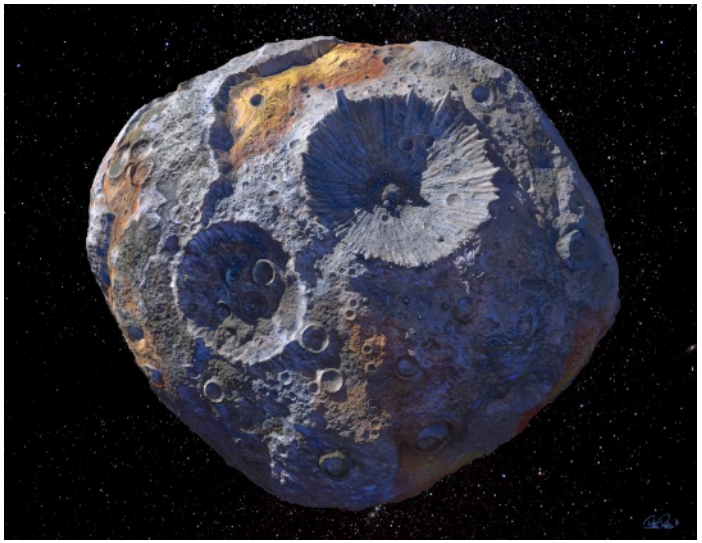
Planning on using a Validation mindset even down to the subsystem level

- Working with all the subsystem teams to clarify their validation plans along with verification

- Ensuring we understand how the subsystem works from a qualitative level,
  - Have we tested all the states that the subsystem can operate in (required or not)
  - Have we explored intermediate inputs and states of the sub-system, dose the subsystem degrade benignly or does it fall off a cliff
  - Have we done an end to end test of the data, power, electrical flow through the subsystem in a flight like manner and environment

What's next

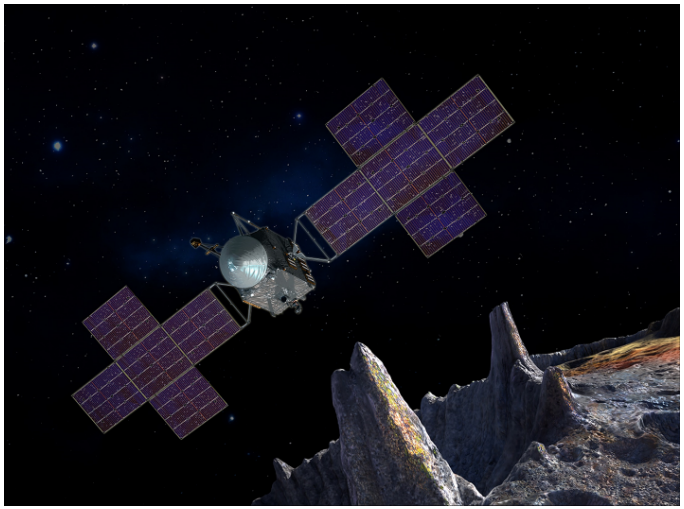
- Preliminary Design Review – week of March 12, 2019
  - KDP-C follows soon after
- Between PDR and CDR
  - Verification Activity Plan & procedure development
  - Stress/Risk Reduction/Robustness test development
  - Prepare our Validation Matrix
- CDR in mid-2020
- Launch scheduled for August 2022

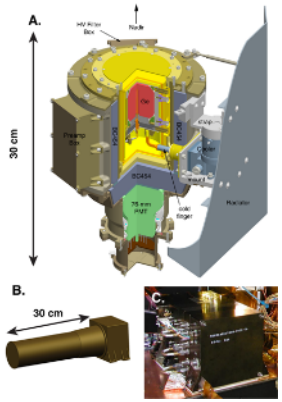



ASU School of Earth and Space Exploration
Arizona State University
APL
+
UCLA
NASA Jet Propulsion Laboratory
California Institute of Technology
+
SSL
IPGP
Yale
DLR
MIT
GRC
GLENN RESEARCH CENTER
at Lewis Field
Smithsonian
SwRI
PSI
Planetary Science Institute

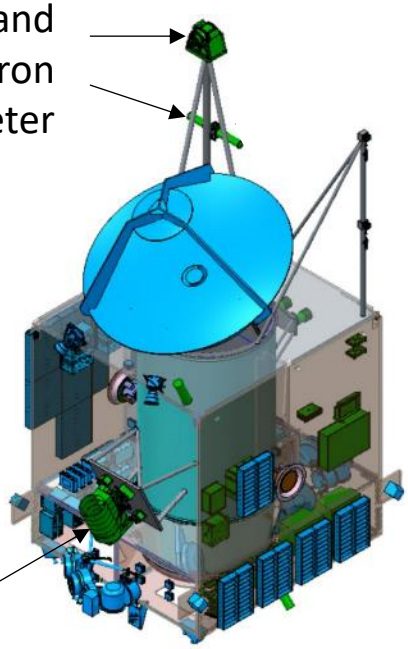
Psyche Mission Concept

- Three instruments, one technology demonstration
- Spacecraft bus fusion of two partners:
  - Space Systems/Loral (SSL)
  - Jet Propulsion Laboratory (JPL)
- Leverages key strengths of each partner
  - Electric propulsion, high power S/C (SSL)
  - Deep space communications, autonomy (JPL)

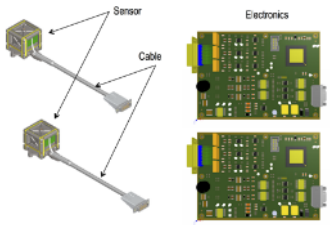


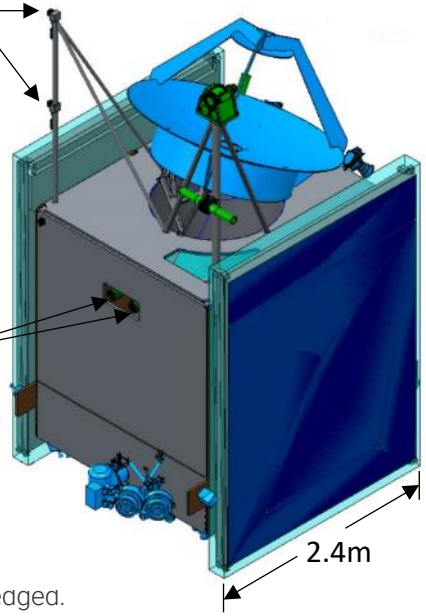


Gamma Ray and Neutron Spectrometer



Magnetometer Sensors





Imagers

Deep Space Optical Communications

ernment sponsorship acknowledged.

Early V&V allowed us to take a hard look at the testbeds that we would need

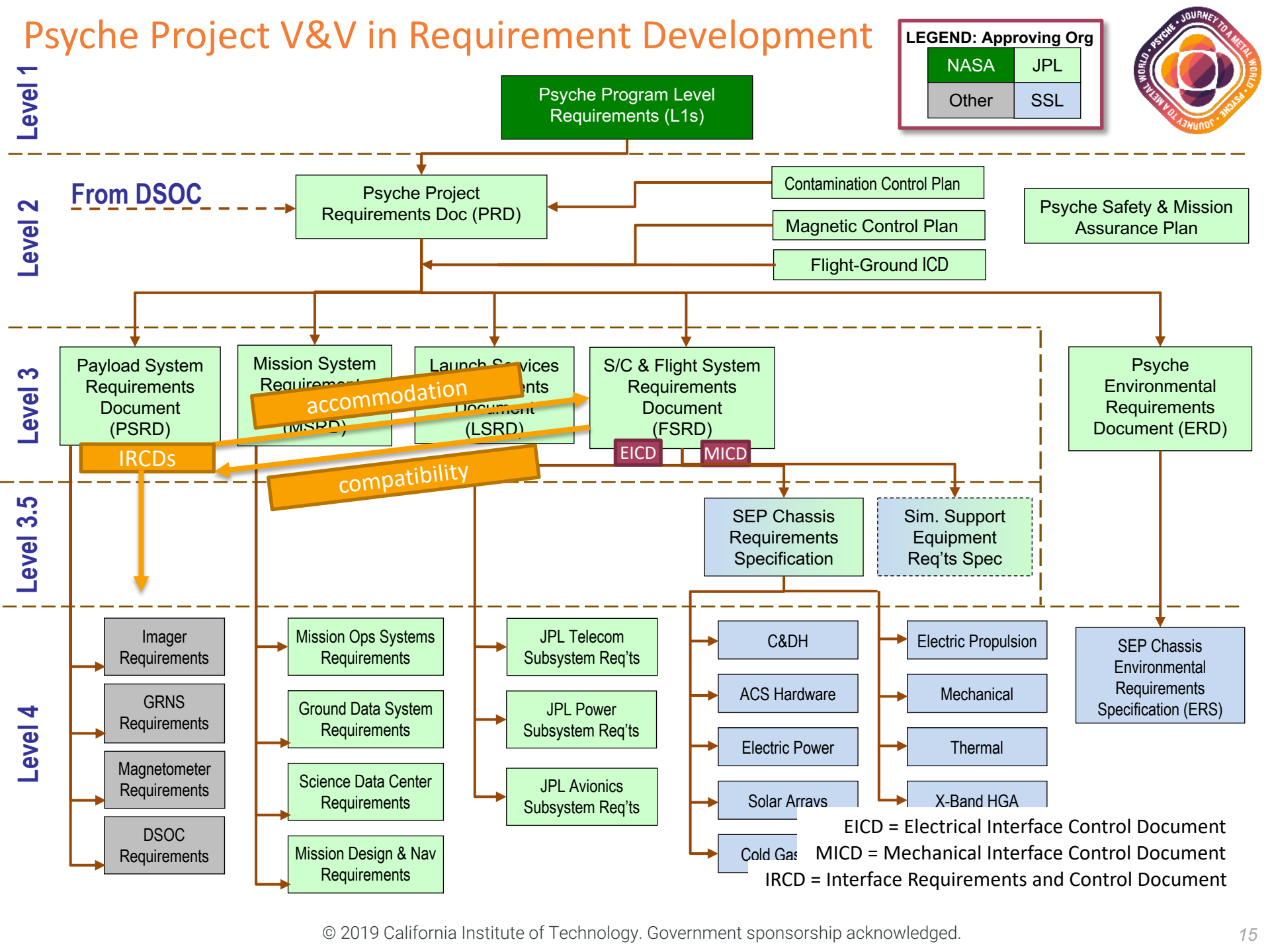
	JPL	SSL	FSWTB	FSTB
C&DH Subsystem				
PCE A			EM	EM
PCE B			Sim	EM
ACE A			Sim	EM
ACE B			Sim	EM
RS485 Router			Sim	EM
ESIAM-A			Sim	EM
ESIAM-T			Sim	3 1
EHCT			Sim	5 1
Pyro Tray			Sim	2 1
EMPD (DTU)			Sim	EM
ESDU				
Relay Tray			Sim	3 2
Electrical Power Subsystem				
PDA A			Sim	EM
PDA B			Sim	Sim
Battery (EPS 2.0)			Sim	Sim
Smart Battery Tray			Sim	EM
Solar Array			Sim	Sim
SADA			Sim	Sim
PCU			Sim	Sim
PHU				
PPU			Sim	Sim
50W DC/DC (DTU)			Sim	EM
ACE PDU			Sim	8 6

	JPL	SSL	FSWTB	FSTB
Attitude Control Subsystem				
Sun Sensors			Sim	Sim
RLG / MIMU			Sim	Sim
Star Trackers			Sim	Sim
RWAs			Sim	Sim
Telecom Subsystem				
SDST			Sim	Sim
TWTA			Sim	Sim
WGTS			Sim	Sim
LGA				
Propulsion Subsystem				
Cold Gas Thrusters			Sim	Sim
Hall Thrusters			Sim	Sim
Payloads				
MAG			Sim	EM
GRNS			Sim	EM
Imager (DEA/Head)			Sim	EM
DSOC			Sim	EM

Color Code:

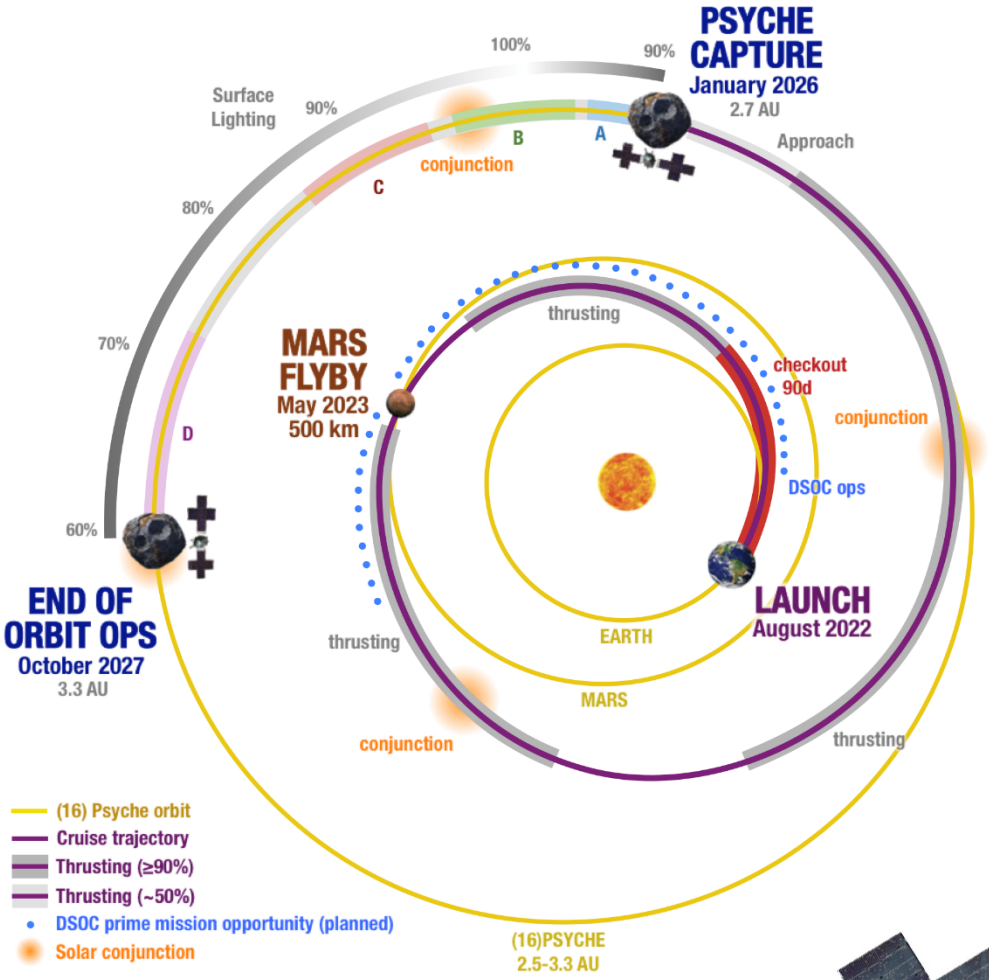
Full Heritage	EM
Partial Heritage	Sim
No Heritage	Not Sim'd/Not Present

Psyche Project V&V in Requirement Development



Mission Design Overview

Cruise: 3.4 years



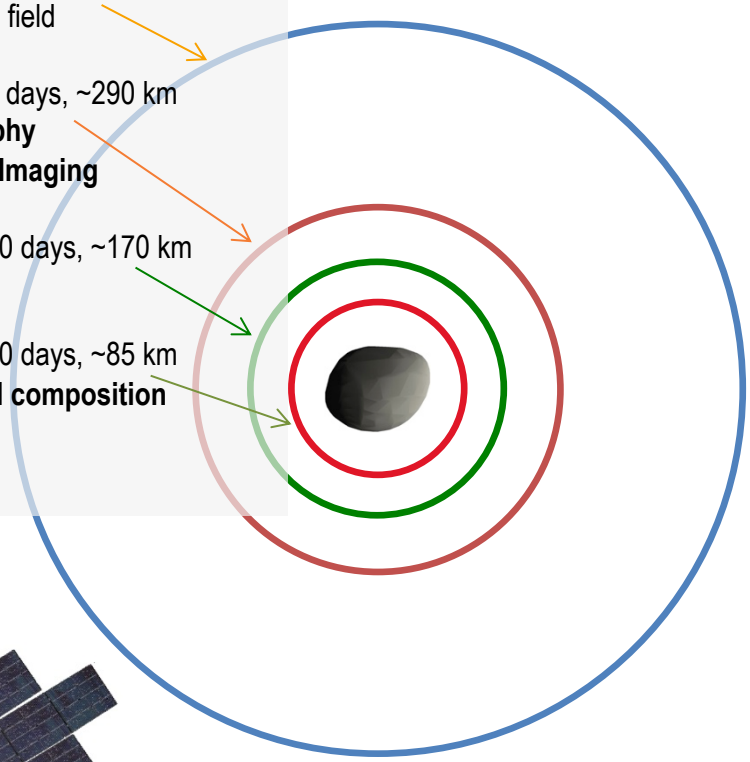
Orbital Science Operations: 21 months

Orbit A: 56 days, ~700 km
Magnetic field

Orbit B: 76 days, ~290 km
Topography
Spectral Imaging

Orbit C: 100 days, ~170 km
Gravity

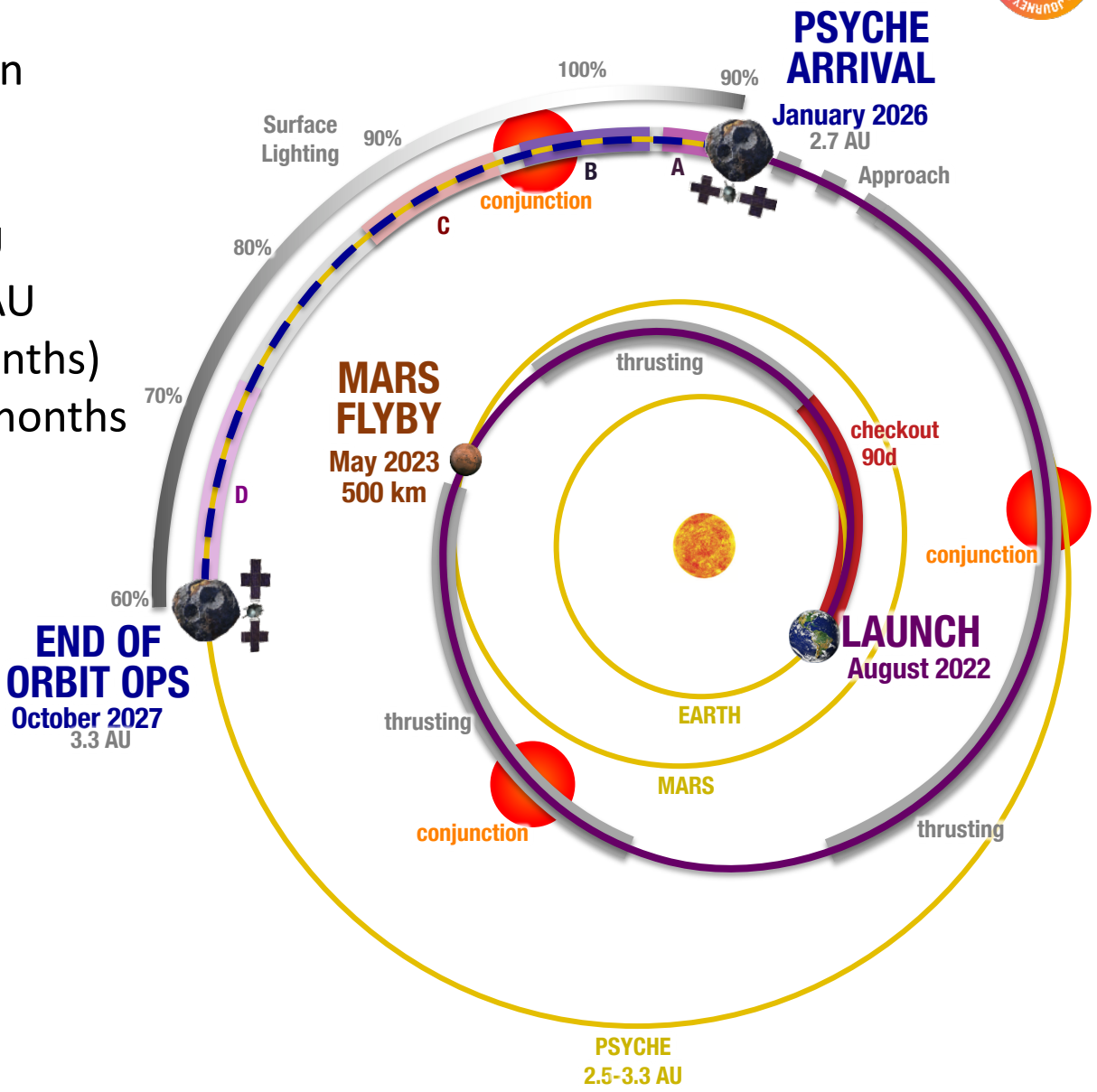
Orbit D: 100 days, ~85 km
Elemental **composition**



Five panel solar arrays
~20 kW BOL

Baseline Mission Design

- Dawn-like mission design
- Launch from KSC
- Mars Flyby (500 km)
- Min Solar Range: 1.0 AU
- Max Solar Range: 3.33 AU
- Cruise: 3.5 Years (42 months)
- Orbital Operations: 21 months



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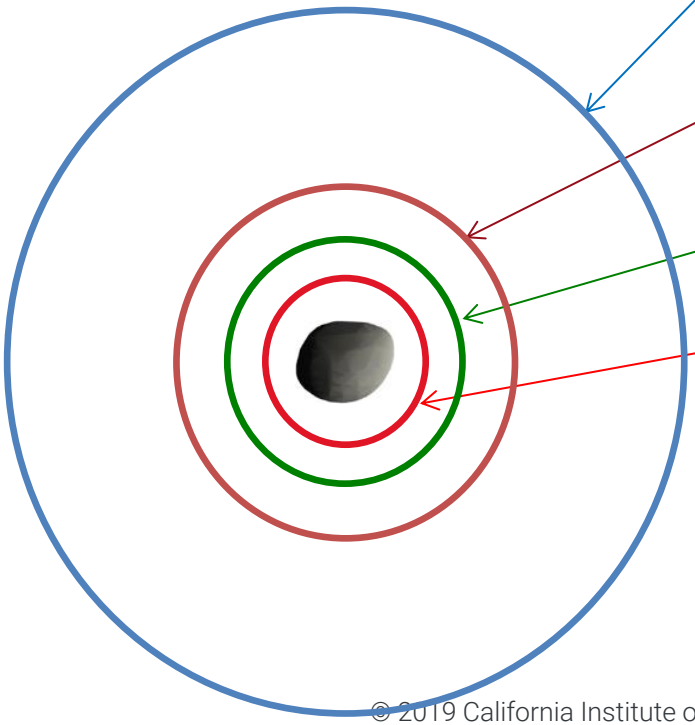

Orbit A: 56 days (41 orbits @32.4 hrs, ~700 km alt)
Magnetic field detection L1 requirements

Orbit B: 76 days (162 orbits @11.2 hrs, ~290 km alt)
Topography L1 requirements
Spectral Imaging L1 requirements

Orbit C: 100 days (369 orbits @6.5 hrs, ~170 km alt)
Gravity Science L1 requirements

Orbit D: 100 days (585 orbits @4.1 hrs, ~85 km alt)
Elemental composition L1 requirements

Test Venues for AVS Activities

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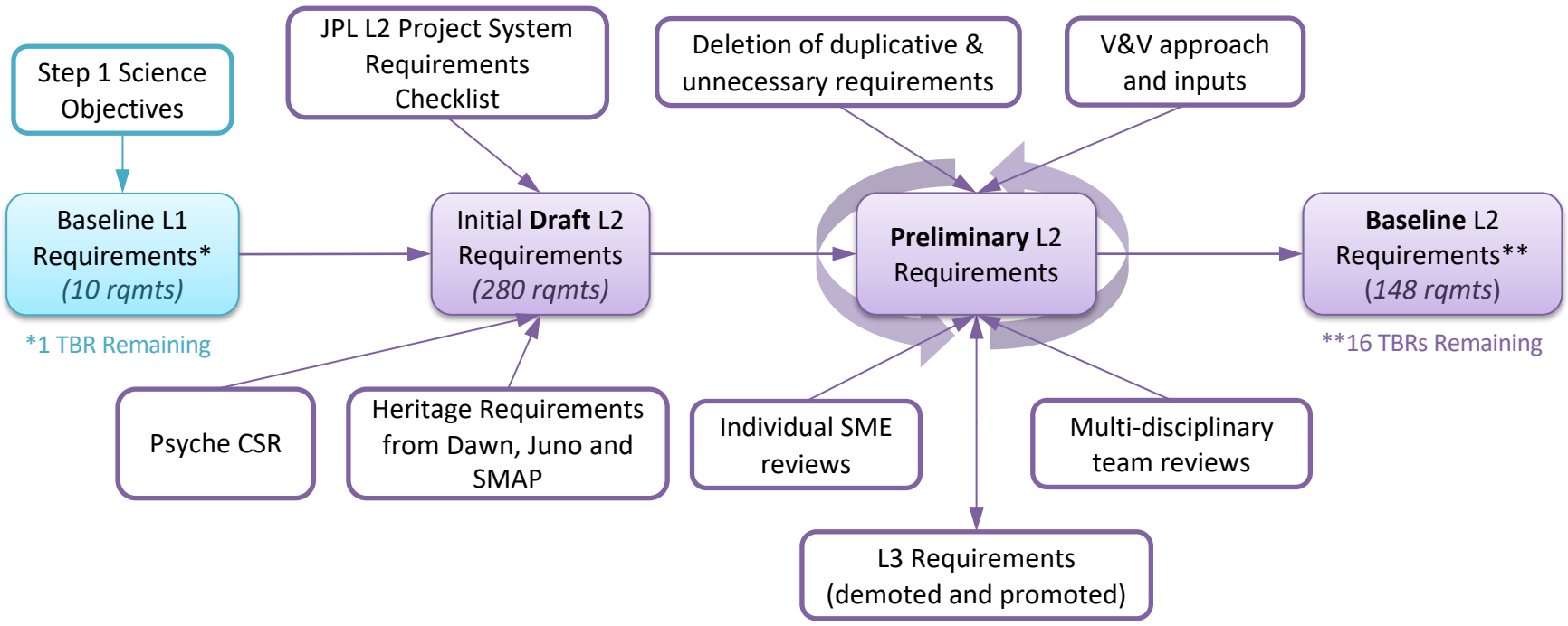
Requirements Development Process

- Level 1 Requirements: reviewed during Step 2 proposal and iterated with NASA HQ
- Level 2 and Level 3 Requirements: derived using iterative development process
- Verification approaches developed with requirements
- Make sure requirements are verifiable
- Requirement Validation (how do you know when you have a complete set?)

Example: Level 2 requirement development process



Flight System Implementation Overview

SEP Chassis I&T (at SSL)

Structure & Antenna

Thermal Control

Power & Propulsion

ACS Sensors & Actuators

SSL

SEP Chassis Assembly

Early Data Flow Demos

Install & Deploy Solar Arrays

Solar Arrays

Legend

SSL Deliverables

JPL Deliverables

I&T Activities

Flight-Like Equipment Panel

Remove Solar Arrays & Ship to JPL

Xenon and Loading GSE

Flight System I&T (at JPL)

JPL

Eng Model PCE Early Version FSW

Mech GSE

Mainbody

Solar Arrays

Power, PCE, Telecom Gear

Magnetometers

GRNS

Imagers

DSOC

Pathfinder Tabletop Testing

Powered Functional Testing

Environmental Testing

Xenon Loading

Ship to Launch Site

Full Capability FSW

FSW Updates